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80th REPORT of the STATE GEOLOGIST

1987-88

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DIVISION OF MINES AND GEOLOGY

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80th REPORT of the STATE GEOLOGIST

1987 - 1988

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FOREWORD

This 80th Annual Report of the State Geologist summarizes the major activities of the Division of Mines and Geology during Fiscal Year 1987-88 and discusses the most significant geoscience issues: How do mineral resources and geologic hazards affect the quality of life in California? How can our mineral resources be used more wisely? What steps should be taken to mitigate geologic hazards?

This report clearly illuminates the increasingly stiff competition for use of the State's terrain. Its readers will be better able not only to understand the geologic problems facing California but also to develop informed opinions about their solutions.

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CONTENTS

INTRODUCTION vi
MINERAL RESOURCES 1
URBAN MINERAL RESOURCES 1
Urban SMARA 1
Effectiveness of Urban SMARA 1
NON-URBAN MINERAL RESOURCES 2
Non-Urban SMARA 2
Effectiveness of Non-Urban SMARA 2
Senate Bill 7 and the Desert Plan 3
OFFSHORE MINERAL RESOURCES 6
MINED LAND RECLAMATION 7
Compliance with SMARA 7
Abandoned Mine Reclamation 7
GEOLOGIC HAZARDS 9
EARTHQUAKE HAZARDS 9
Faulting Hazards 9
Shaking Hazards 12
Engineering Hazards 13
Preparation and Response 14
VOLCANIC HAZARDS 17
LANDSLIDE HAZARDS 18
URBAN GEOLOGIC MAPPING 20
CONCLUSIONS 20
APPENDIX 21

INTRODUCTION

Recent Annual Reports of the State Geologist described the projects of the Division of Mines and Geology (DMG) and their products. This year's report is different. It is meant to focus not so much on the projects of the Division as on the most important earth science issues facing California. This shift in attention reveals the primary mission of DMG — to help address these issues.

According to the Public Resources Code, the Annual Report of the State Geologist shall include a section reviewing the status of measures taken in the State to counter geologic hazards and a section reviewing the economic utilization and conservation of the State's mineral resources. This is a broad mandate — basically a "State of the State's geology." This year's report discusses only the most important earth science issues currently facing the State and the most significant ways in which DMG is grappling with them.

The primary mission of the DMG, the State's geological survey, traditionally has been to develop the means by which the basic information generated by universities, the Federal and State governments, and private companies, was put to use. Most scientists in the DMG are applied scientists, that is, they apply the discoveries of others. The DMG is thus charged with compiling and disseminating existing geologic data.

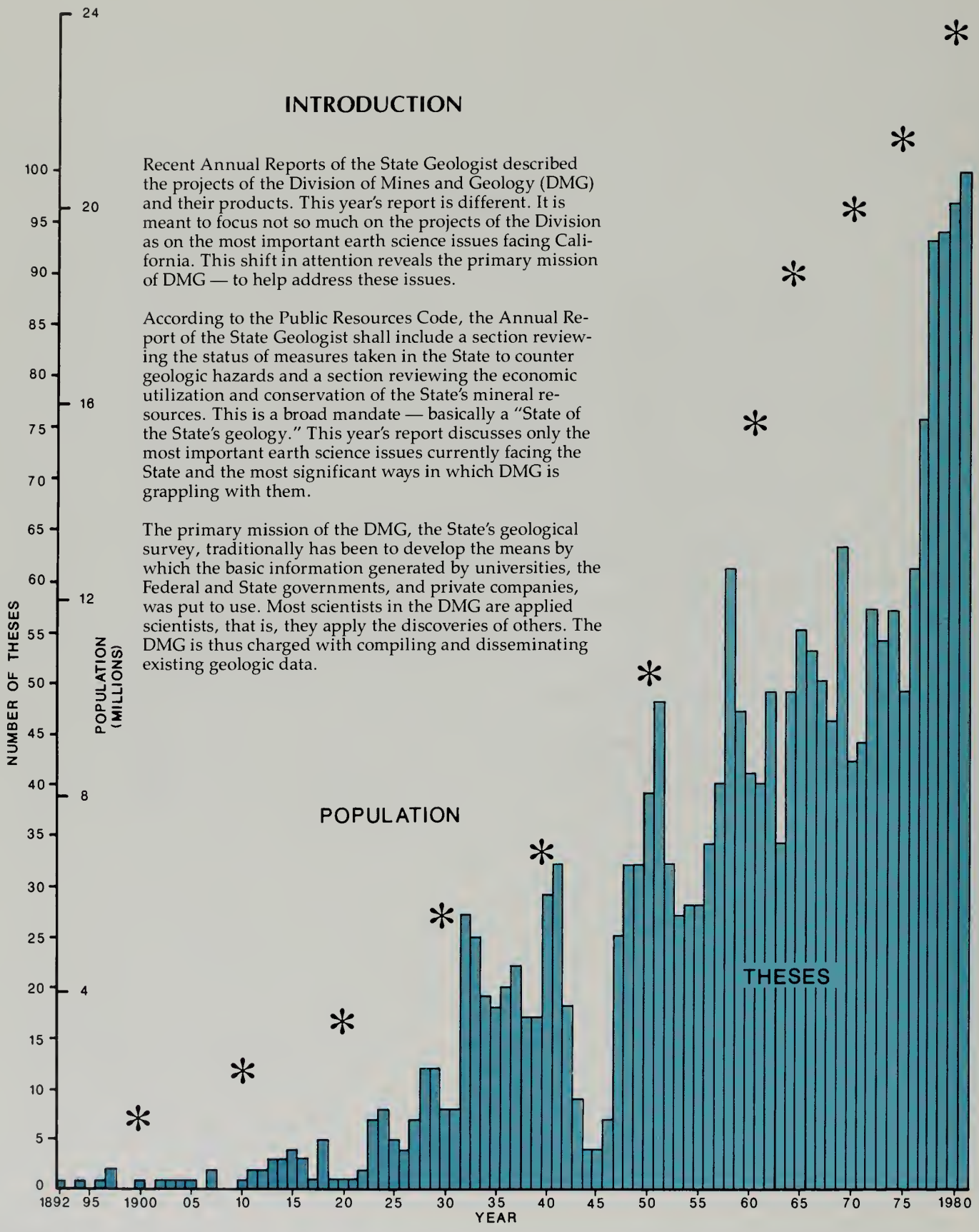


Figure 1. Expansion of earth science information as measured by the number of theses produced each year in relation to the population of the state.

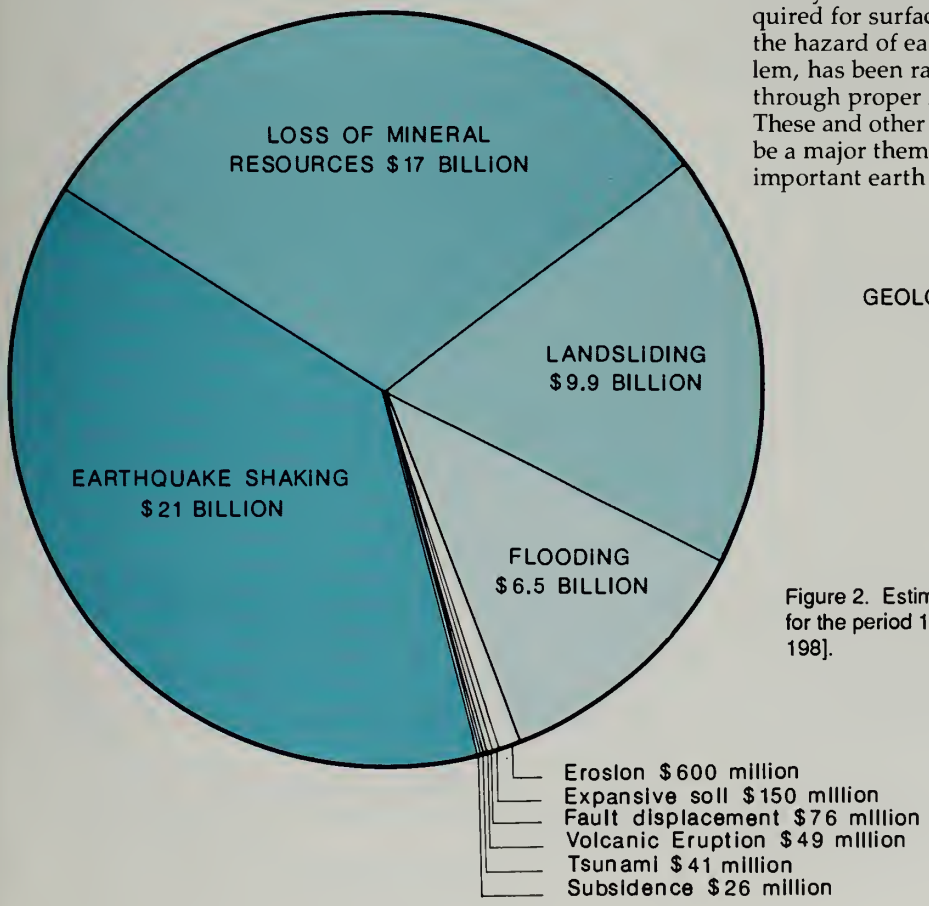
Another mission of the DMG is to generate, when necessary, new information. This basic work may include, for example, the evaluation of the mineral potential or the landslide potential of a particular region. It includes the generation of geophysical, geological, and seismological data for areas where such data are lacking.

The social environment in which DMG does its work is dominated by the continuing explosion of California's population. The population in the Los Angeles area, for example, will increase from 12 million in 1984 to 18 million in 2010. This growth will result not only in a 50 percent increase in the demand for crucial mineral resources, but also in a decrease in the accessibility of those resources. Further, because most of the building sites in the Los Angeles area that are readily suited to development are already taken, each new development has an increasing likelihood of being at risk from geologic hazards. Thus, population pressure is forcing public officials to make decisions that cannot easily be reversed concerning our rapidly shrinking open space. Earth science information must be included in the decision-making process if wise choices are to be made.

The amount of earth science information has expanded along with the population of the State (Figure 1). Theories used to interpret these data have improved as well. For example, before the San Francisco earthquake of 1906, scientists were not even certain that faults and earthquakes were related. As recently as 1960, we were unaware that two major tectonic plates met in California and that their relative motion has determined and is determining the State's geology. The increase in data and the development of theory makes the task of the State's earth science applicators all the more difficult and useful to the citizens of the State.

In recent years, DMG's work has been guided partly by the findings of *Urban Geology: Master Plan for California*, a report issued by the Division in 1973. *Urban Geology* was an economic analysis of the various mineral resource and geologic hazard problems facing the State between 1970 and 2000. As shown in Figure 2, this analysis concluded that if nothing was done to counteract earthquake shaking, the State could lose up to $21 billion during that 30-year period, the loss of mineral resources could amount to $17 billion, and the losses due to landsliding could amount to $10 billion. The total potential losses to geologic hazards were estimated to be $55 billion. *Urban Geology* further concluded that major reductions could be made in those losses: $11 billion (out of the $21 billion total) in earthquake shaking, $15 billion (out of the $17 billion total) in mineral resources, and $9 billion (out of the $10 billion total) in landsliding.

Because we have passed the half-way point in that 30-year projection, it is timely to evaluate how well California has done in reducing those potential losses. While this report is not a comprehensive account of the State's performance in this regard, it clearly shows that much has been accomplished. The loss of mineral resources, particularly sand and gravel near rapidly urbanizing areas, has been significantly reduced. Effective reclamation plans are now required for surface mining operations. Public awareness of the hazard of earthquake shaking, a less tractable problem, has been raised. The mitigation of landsliding through proper zoning and grading has been started. These and other practical applications of earth science will be a major theme of this report as we examine the most important earth science issues raised during the year.



GEOLOGIC HAZARDS IN CALIFORNIA
TO THE YEAR 2000:
A $55 BILLION PROBLEM

Figure 2. Estimated losses due to geologic hazards in California for the period 1970-2000 [from "Urban Geology," DMG Bulletin 198].

Photo 1. Oblique aerial view of a sand and gravel pit in the Los Angeles Basin. Sand and gravel, termed "aggregate," is an essential commodity for our rapidly urbanizing society. California is the largest producer of aggregate in the United States. *Photo courtesy of DMG photo file.*

MINERAL RESOURCES

URBAN MINERAL RESOURCES

ISSUE: *Sand and gravel deposits in rapidly urbanizing areas were undervalued and unprotected prior to 1975.*

URBAN SMARA

California's sand and gravel industry is the largest in the nation: over $661 million of construction aggregate was mined from 503 pits and quarries in the State in 1986. Ironically, the aggregate industry has been threatened by its own productivity. The construction that depends on this industry creates land use pressures that often force premature closure of mines on the urban fringe. Without proper long-term planning, structures are built on or adjacent to sand and gravel deposits, threatening to make those deposits unavailable as sources of aggregate. In an industry where costs are dominated by transportation distances, aggregate pits and quarries must be sited as close to their urban markets as possible. An aggregate pit, which was situated in a rural area decades ago, today finds residential subdivisions along its boundaries and concerned neighbors at its use-permit hearings (Photo 1). The social and economic consequences of inadequate planning are high, increasing both consumer cost and environmental damage and putting the industry at odds with the community it serves.

This problem — the premature loss of mineral resources — was formally recognized and quantified in *Urban Geology*. In 1970 it was estimated that $17 billion worth of resources, primarily construction aggregate, would be precluded from mining by the year 2000 if current land use practices continued. It was also estimated that 90 percent of this loss could be prevented if economic geology studies, including systematic resource deposit inventories, were used in the local planning process. This recommendation was incorporated into State law in 1975, when the California Legislature passed a bill establishing the Surface Mining and Reclamation Act of 1975, commonly known as SMARA.

SMARA addressed two issues of concern to the California electorate — continued mineral availability and adequate mined land reclamation — while preserving California's long tradition of local autonomy and authority in land use planning. Under SMARA, local government retains all land use decision-making authority (a constitutionally guaranteed right in California) relative to the granting of mining permits. Responsibility for preparing an accurate, quantified data base for aggregate resource was given to the State. The success of SMARA depends upon cooperation between the State and local governments with State government having the responsibility for resource inventory and the local government having the responsibility for the protection of those resources (Photo 2).

Photo 2. DMG geologist collects samples in the field. *Photo by DMG staff.*

EFFECTIVENESS OF URBAN SMARA

Urban Geology estimated that 90 percent of potential mineral losses, or $15 billion, could be prevented through preparation of a statewide resource inventory, and better long-term local planning based on that inventory. At an estimated cost of $90 million, a benefit/cost ratio of 170/1 was calculated under those assumptions.

Assuming an average price of only $3.88 per ton (the 1986 average statewide price at the plant), then $295 billion of aggregate resources have been identified and protected so far. Even assuming conservatively that lead agencies are able to protect only 10 percent of the identified reserves and resources (7.6 billion tons worth $29.5 billion), a benefit/cost ratio of almost 5,000/1 will have been achieved. These benefit/cost ratios do not include the benefits from reduced transport distances or the costs incurred by local governments for planning and permitting. In spite of the difficulties of calculating the benefit/cost ratio for the urban SMARA program, it is clear that aggregate resources have been preserved for future construction within today's rapidly urbanizing areas.

NON-URBAN MINERAL RESOURCES

ISSUE: *The mining of mineral resources competes with other land uses.*

NON-URBAN SMARA

SMARA was amended in 1980 to include non-urban areas of the State where significant mineral resources could be lost because of land use decisions incompatible with mineral extraction and conservation. The two areas of highest priority were the California desert area and the foothills of the Sierra Nevada. In 1980, the desert area, representing about one-fourth of California, was being studied by the Bureau of Land Management (BLM) in preparation for a general land use management plan and for inclusion into the National Wilderness and Park System. The Sierra Nevada foothills were chosen because they are highly mineralized and are undergoing urbanization at a rapid rate.

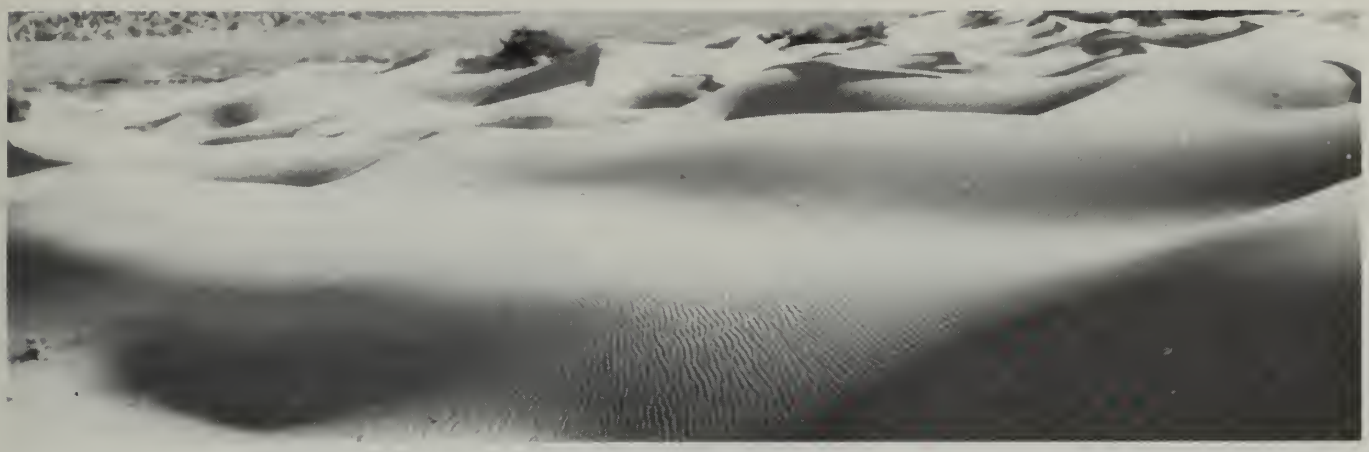
In 1981, SMARA studies were begun in the foothils and in the desert. These studies consist of the preparation of a mineral land classification report, which is a geological inventory of selected mineral commodities within a prescribed region. These reports include an identification of the market area of the commodities, a 50-year projection of the needs for the commodities within the market area, and a map of the region showing presence of or potential for the commodities. Mineral classification reports and maps have been prepared for approximately 2,200 miles of the Sierra Nevada foothills and about 5,500 square miles of the California desert.

EFFECTIVENESS OF NON-URBAN SMARA

Significant deposits of gold, tungsten, chromite, copper, magnesite, mica, volcanic cinders, bentonite, carbonate rock, clay, talc, iron, rare-earth elements, and pyrophyllite have been identified in the study areas. Some of these deposits are currently in production and the rest represent important resources that could be made available if needed (Photo 3).

There has been considerable demand for DMG's mineral land classification reports from a broad cross section of society. The Bureau of Land Management has used the DMG studies in its public presentations to illustrate the

Photo 3. The Goldstripe Mine near Canyon Dam in Plumas County was originally mined for gold in 1842. After a period of inactivity, recent exploration at the mine began in the early 1980's. *Photo by John L. Burnett.*



mineral wealth of the desert. For county planning departments, these studies are important in land use decisions. Exploration companies find them valuable in strategic planning.

In 1987 a major land use issue concerned the California desert (Photo 4) and provides a good example of the need and application of the Non-Urban SMARA program. This issue is worthy of special discussion.

SENATE BILL 7 AND THE DESERT PLAN

U.S. Senate Bill 7 (S.7), referred to as Senate Bill 11 in Fiscal Year 1988-89, would establish a National Park covering much of the eastern Mojave Desert in California (Figure 3). It would greatly expand Death Valley National Monument and give it National Park status. It would establish a Joshua Tree National Park and reserve most of the remaining desert mountain ranges as wilderness areas. Exploration for and development of new mineral resources would be prohibited in these areas and existing mining operations would have increased restrictions.

While it is clear that the growing southern California population will need additional recreational opportunities, the proposed land use may not have adequately recognized the importance of the mineral resource potential of the region (Figure 4). The nonfuel mineral production of the U.S. was $25 billion in 1987 with 10 percent coming from California. More than half of the California production ($1.4 billion) came from the California desert. It contains the world's largest producer of borate and the country's largest producer of rare earths, which are likely to be crucial ingredients in the superconductors of the future. It has significant tungsten, gypsum, specialty clay, and sand for the manufacture of glass, and is a major source of materials for the manufacture of cement.

In the California desert, about 80 percent of the areas originally considered by BLM for the National Wilderness System have been surveyed for their mineral potential by the DMG. Some of the additional area included in S.7 has been evaluated, but a substantial part remains unassessed. Based on our previous studies of mineralization in the desert, we expect that significant additional mineral resources in the unstudied areas will be present.

A thorough evaluation of the desert's mineral resources is necessary to make wise land use decisions. With a population of 18 million expected for southern California by the year 2010, planners recognize the long-term importance of mineral resource production on the regional economy. The land use decisions regarding the California desert will have a profound effect on the State's ability to

Photo 4. Dunes in the Mojave Desert. *Photo by DMG staff.*

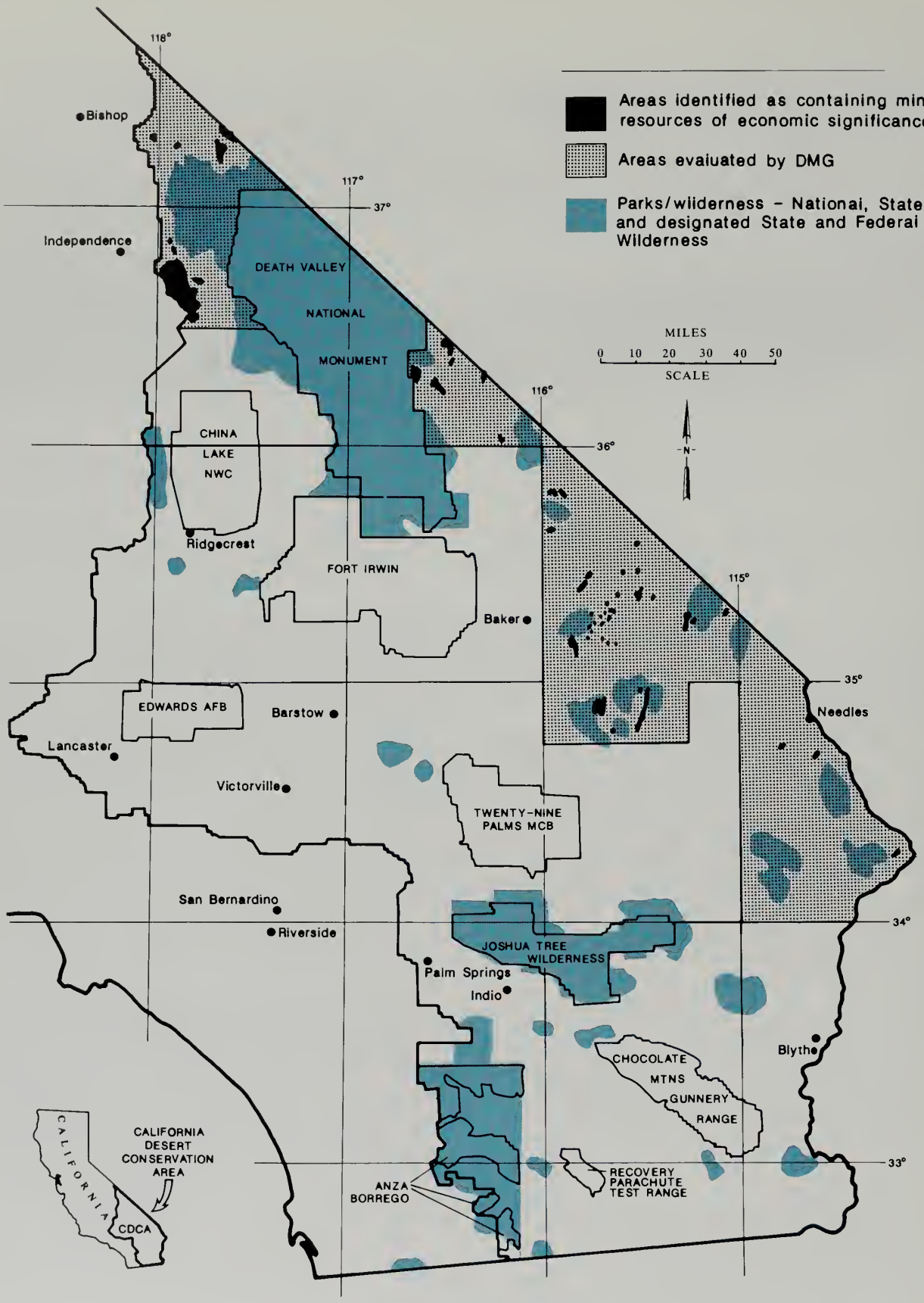


Figure 3. Map of the Mojave Desert showing Mineral Resource Zones superimposed on the current California Desert Plan.

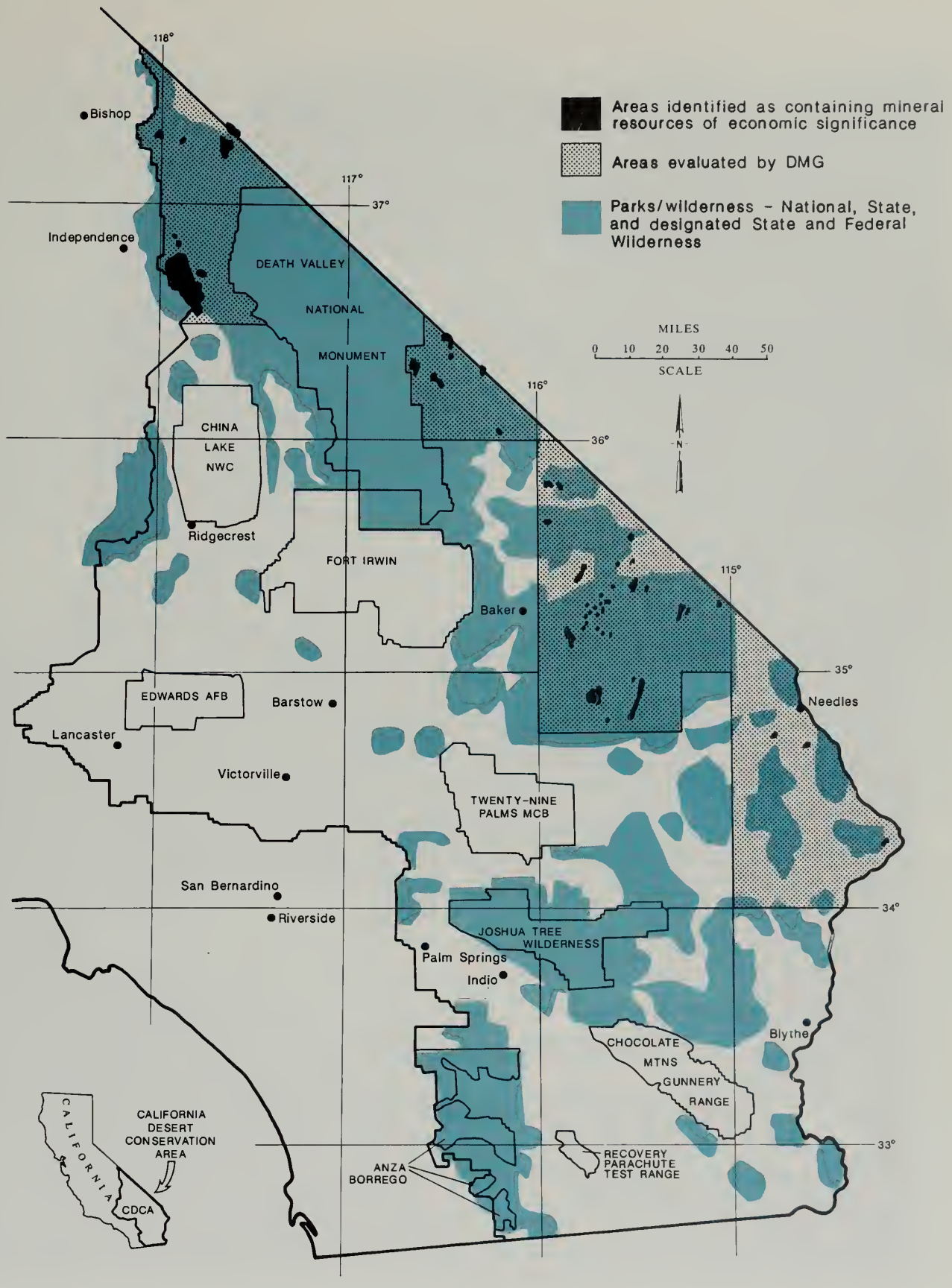


Figure 4. Map of the Mojave Desert showing Mineral Resource Zones superimposed on the Proposed Desert Legislation (Senate Bill 7).

provide an affordable source of mineral materials. Because the costs of construction and the competitiveness of local industries are partly dependent on the cost of the minerals, important land use decisions require accurate knowledge of mineral resources. Mineral land classification in the California desert should be completed before decisions are made to withdraw land from use.

OFFSHORE MINERAL RESOURCE

ISSUE: *The potential value of the State's offshore mineral resources has not been assessed.*

The State of California controls a tract of land offshore 3 miles wide and 850 miles long that could contain significant mineral resources. Modern technology is rapidly making the sea floor accessible to mineral exploitation. The State should know the potential value of the mineral resources of this area in order that these resources are wisely used.

The DMG, in cooperation with the U.S. Geological Survey (USGS), is publishing a series of seven 1:250,000-scale geological maps of the offshore area. These maps are compilations of data obtained from offshore oil well drilling, sampling by research vessels (Photo 5), and surveying with sensitive geophysical instruments. By comparing the geologic units mapped offshore with similar units onshore, the mineral potential of the ocean floor can now be more confidently evaluated.

A preliminary examination of these DMG-USGS offshore geologic maps shows that California's offshore area has extensive sand and gravel resources, the State's number one mineral product. This aggregate might be economic to mine when coastal cities have built upon or depleted existing deposits. Magnetite and phosphate occurrences (like those documented in waters off Mexico) have also been identified while titanium and zirconium deposits (similar to those located off the coasts of Oregon and Mexico) are possible. These are a few of the resources that are used in high technology products and that could be mined offshore California given technological developments and social needs.

Photo 5. Deep sea submersible *Alvin* being launched by its mother ship *Atlantis II*. *Alvin*, which has been in operation since 1964, is a U.S. Navy-owned national oceanographic facility and is jointly supported by the National Science Foundation, the Office of Naval Research, and the National Oceanic and Atmospheric Administration. It can accommodate a pilot and two scientists, and can submerge for 72 hours to depths of over two miles. It can roam the sea floor and is equipped with sampling devices (two arms and a claw). *Photo courtesy of Woods Hole Oceanographic Institution.*

Photo 6. One of California's many abandoned mines.

MINED LAND RECLAMATION

ISSUE: *The laws for mined land reclamation need to be implemented more thoroughly.*

COMPLIANCE WITH SMARA

SMARA legislation was a compromise in which the rights of mine operators were protected while their obligations to restore the environment were defined. Assembly Bill 747, effective January 1, 1988, clarified the law for vested operators (i.e., those who were operating before enactment of SMARA in 1975) by requiring that reclamation plans be submitted to local permitting agencies no later than March 31, 1988. After July 1, 1990, surface mining operations without reclamation plans must shut down until plans are submitted.

Special Publication 93, "Mines and Mineral Producers Active in California During 1986," was published by the DMG in 1987. In collecting the data for that publication, DMG determined whether or not a reclamation plan existed for each operation. Next, owners of mines without reclamation plans will be contacted to determine if they are aware of the provisions of the law.

Eventually, information on mines in noncompliance will be turned over to the State Mining and Geology Board for further action.

Enforcement of SMARA is the responsibility of lead agencies, which in most cases are local governments. Implementation of SMARA is the responsibility of the State. SMARA and its regulations require lead agencies to forward a copy of all reclamation plans and mining permits to the DMG. Lead agencies have been reminded in a letter from the State Geologist of these requirements.

ABANDONED MINE RECLAMATION

Because there was active mining in California for more than a century prior to the enactment of SMARA, many mines were abandoned and never reclaimed (Photo 6). Some of these mines may pose a threat to public safety; some reduce the productivity of the land. All remind the public of the impact of outdated mining practices on the environment.

Currently, the State has no program to address this problem. Some states receive Federal money for reclaiming abandoned mines that pose an immediate threat to public safety. This money comes from funds collected from coal production. Because California has negligible coal production, very little Federal money is available to establish an abandoned mine reclamation program.

The problems posed by abandoned mines in California deserve evaluation. We must know how many such mines exist, their threat to public safety, and their influence on the esthetics and productivity of the land. The DMG will be studying this issue in the future.

Photo 7. Fault displacement at Kagel Canyon in Los Angeles County caused by the 1971 San Fernando earthquake. *Photo by Charles R. Real.*

GEOLOGIC HAZARDS

EARTHQUAKE HAZARDS

ISSUE: *Many parts of California face an earthquake threat that could result in thousands of casualties and in billions of dollars of damage.*

Scientists have made significant progress in understanding the earthquake-caused damage during the last century. The idea that earthquakes are related to fault movement was first expressed in the 1880's. The proof of that idea was found in the study of the Great San Francisco Earthquake of 1906 (Photo 8). With up to 18 feet of ground rupture, the influence of the San Andreas fault was obvious. Californians today know about their seismic faults.

The State Earthquake Commission, set up following the 1906 event, noted that the severity of earthquake shaking and the resulting damage depend not only on the distance from the causative fault and quality of a structure's construction, but also on the type of ground upon which the structure is built. Compared with regions underlain by firm sediment or rock, soft sedimentary basins suffered greater damage, even at greater distances from the earthquake source. For decades following the San Francisco earthquake, however, this knowledge was not applied to reduce losses from earthquakes. Only after the 1933 Long Beach earthquake did the California Legislature pass the Field Act as the State's principal means of mitigating earthquake losses.

Photo 8. Trace of the 1906 earthquake through the Skinner Ranch in Marin County. *Photo by G.K. Gilbert.*

Photo 9. DMG seismologist changes smoke-drum seismograph in the field. *Photo by DMG staff.*

It was not until the 1970's that systematic evaluation of seismic hazards was recognized as a means of reducing earthquake losses. This activity entails identifying potential earthquake sources and mapping areas susceptible to surface faulting, strong shaking, and ground failure. Provisions of such information at regional scales by the DMG during the past two decades have increased awareness of the earthquake threat, and have influenced the siting and design of various structures throughout the State.

FAULTING HAZARDS

The clearest evidence of earthquake hazard potential comes from the historic earthquake record. Most of California's faults have not, however, generated major earthquakes during the State's short history. Fortunately, a fault's potential for future earthquakes and associated ground rupture may be indicated by the recency in geologic times of surface faulting along it.

A three-fold classification system — historic, Quaternary, and pre-Quaternary faults — was used in DMG's 1975 "Fault Map of California," an important tool of government planning agencies, researchers, and industry. However, the risks accepted by users vary widely, so there is some disagreement on the definition of an active fault. Depending upon the type of structure being designed, active faults have been defined variously as those along which slip has occurred in the last 500,000 years, 100,000 years, 35,000 years, 11,000 years, and 200 years.

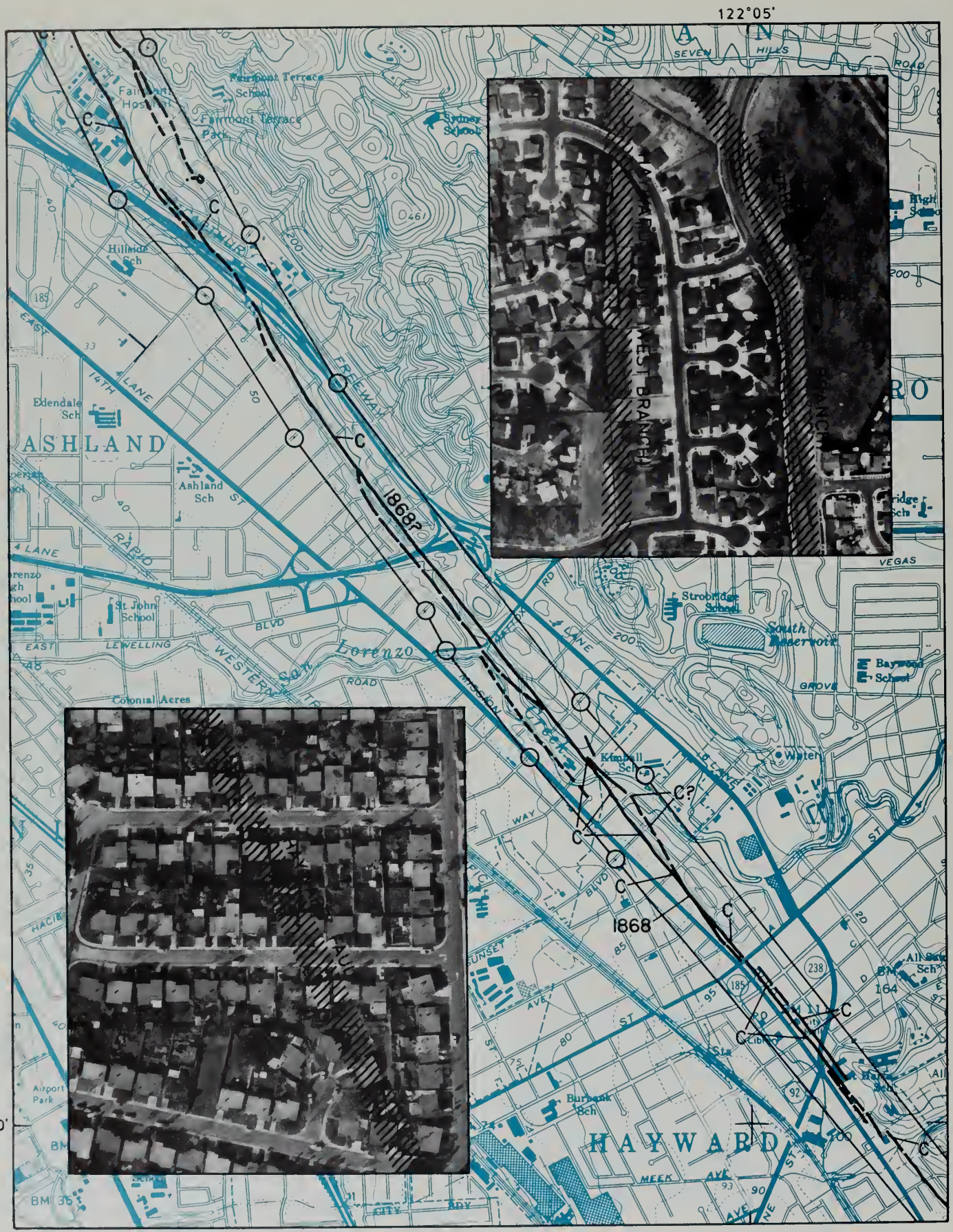


Figure 5. A typical section of an Alquist-Priolo (A-P) Special Studies Zone map (scale 1:24,000). The photo in the lower left typifies the lack of consideration for fault hazards that existed prior to the enactment of A-P legislation in 1972. Photo in upper right is an example of post-A-P development with structures set back from recognized active fault traces.

Perhaps the most practical definition for ordinary structures is the one adopted by the State Mining and Geology Board. The Alquist-Priolo Special Studies Zones Act of 1972 (APSSZ) prohibits building a structure for human occupancy within 50 feet of an active fault. In implementing the law, the Board defined an active fault as one with "surface displacement in Holocene time (about the last 11,000 years) . . ." This definition is used by the DMG, along with the broader term "potentially active" that was equated to Quaternary time (last 2,000,000 years). Although the first Special Studies Zones maps included traces of Quaternary faults, all maps since 1977 are based solely on Holocene fault traces. The purpose of this policy change was to zone only those faults which are estimated to have high potential for future activity. Thus, if a fault has not moved in the last 11,000 years, then the surface-faulting risk to ordinary structures is considered small.

As a result of the Alquist-Priolo Special Studies Zones Act, the DMG has established more than 2,300 miles of regulatory zone. Within these zones, cities and counties must require a geologic investigation for each project that involves more than five single-family dwellings. As a result of these investigations, active faults were found and building setbacks recommended in about 15 percent of the 2,140 reports filed with the DMG so far (Figure 5).

While it is difficult to assess the efficiency of the Act — some active faults creep (i.e., move slowly most of the time) and others lie dormant for tens, hundreds or even thousands of years — it is probable that hundreds of millions of dollars will be saved in property damage in the long run. In one example in the city of Fairfield, a single subdivision is nearing completion along a one-mile stretch of the Green Valley fault. If not for the Act, at least 20 homes might have been placed randomly on the active fault. They were not, as a result of the required geologic investigation. Hundreds of other developments exist along faults throughout California, some involving much more costly structures.

Of the 2,300 miles of faults zoned under the APSSZ Act, it is estimated that several hundred miles of active fault underlie heavily developed metropolitan areas. Some of these areas were developed before the Act, while others were undergoing development when the Special Studies Zones (SSZ's) were established. The Act has been effective in redevelopment areas such as Concord, where some of the old buildings have been torn down and new high-rise buildings constructed. Without the Act, some of the multi-million dollar structures might have been built on the Concord fault.

Effects of the APSSZ Act have extended well beyond its limited requirements. Indeed, local jurisdictions affected by our SSZ's have developed a keener awareness of landslides, seismic shaking, and other geologic hazards. Some have hired review geologists, adopted ordinances, and revised public safety elements. Earth scientists have used data developed incidental to zoning to help determine where large earthquakes will occur. The program has provided useful input for preparation of the State Fault Map, the State Bedrock Acceleration Map, and the Seismic Zone Maps used with the Uniform Building Code.

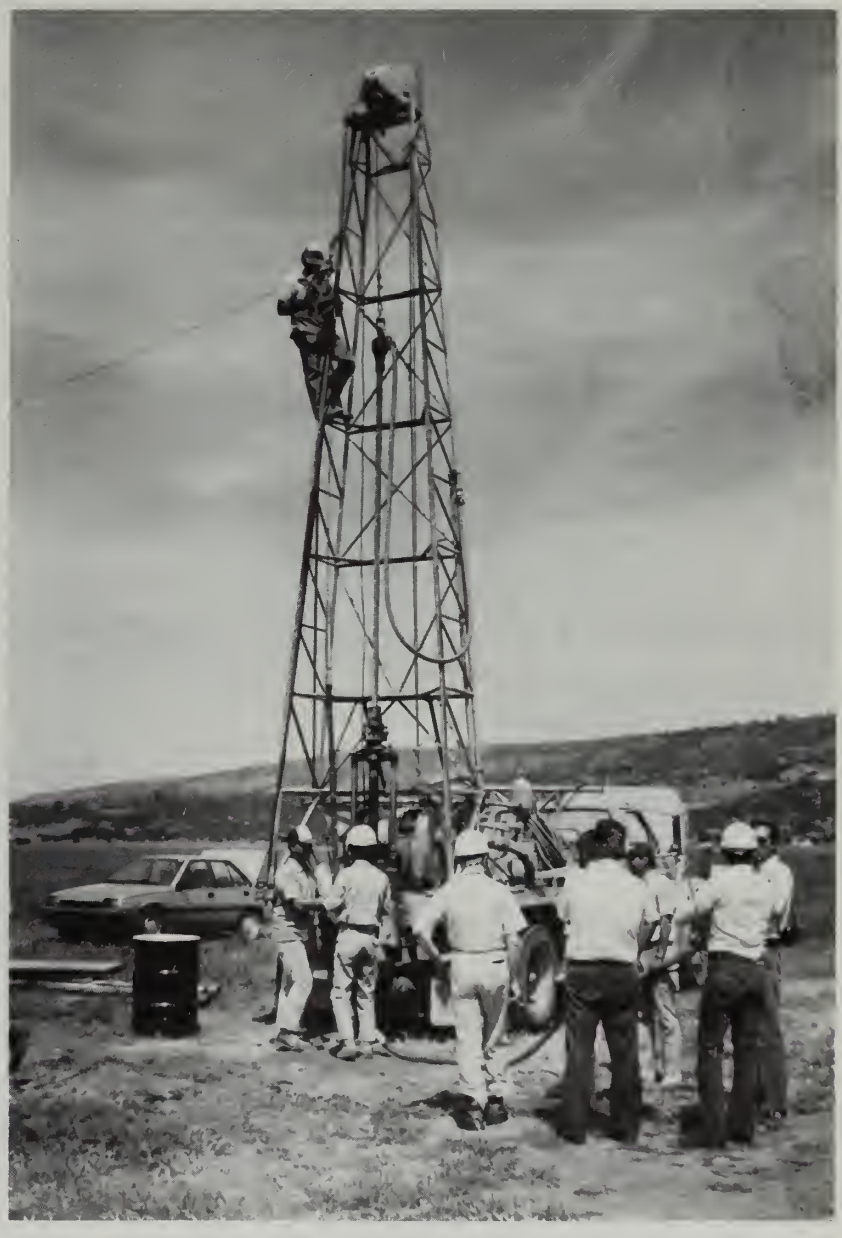


Photo 10. A portable drilling rig used to drill holes for the installation of downhole accelerometers. *Photo by Charles R. Real.*

SHAKING HAZARDS

The 1987 Whittier Narrows earthquake underscored the need to provide detailed information to insurers and local planning officials on the degree of shaking hazard. The methods used to estimate shaking hazard, however, are controversial. The reliability and cost effectiveness of these methods must be established before they can be routinely used to mitigate hazards.

The DMG has initiated two activities to develop and improve methods of assessing shaking hazard: 1) the formation of an international committee of experts in the field of ground shaking and its dependence on geology to oversee the establishment of a series of test sites in seismically active areas of the world that will acquire the necessary data, stimulate research, and promote technology transfer; and 2) the establishment of a test site in California to determine the reliability and cost effectiveness of such methods and serve as a prototype for the international program. These activities are presently well underway.

The test area has been established near Parkfield. Parkfield is a small town in central California, east of Paso Robles and west of Coalinga on the San Andreas fault. Parkfield was chosen for the test site because the U.S. Geological Survey has predicted an earthquake there before 1993.

At the Parkfield test site, the local geologic conditions have been quantified (Photo 10). Eight geotechnical consulting firms and academic institutions in the U.S. and Japan were involved in this effort. A workshop was held by the international committee in Vancouver, British Columbia and 60 specialists representing 15 countries attended. Products from the Parkfield test area, and the international program as a whole, might ultimately be used to establish a shaking-hazard mapping program in California's urban areas that have high exposure to seismic hazards.

Moreover, beginning Fiscal Year 1988-89, the DMG will undertake a study to investigate the feasibility and design of a multi-year Urban Seismic Hazard Mapping Program. It will address the availability of existing data, define end products to meet user needs, and identify the resources needed to carry out a systematic program of seismic hazard assessment in urban areas. Consideration will be given to integrating products from the Alquist-Priolo Fault Evaluation and Zoning Program, the Landslide Hazard Identification Program, and ground shaking and liquefaction assessments into a new "Urban Seismic Hazard Map Series."

Along with local planning departments, the insurance industry is expected to be a primary user of this seismic hazard information. A more detailed knowledge of the shaking hazard could benefit both the insurance industry and the consumer by improving understanding of the geographic dependency of shaking hazard. The availability and cost of earthquake insurance could more closely reflect the actual risk in a given locality, leading to improved solvency and more equitable premiums statewide. Consumers would get realistic information on the degree of risk and the appropriate insurance coverage.

Earthquake Shaking Hazard Map

Given accurate estimates of the strength and duration of shaking likely to occur, engineers can build structures to withstand major earthquakes. In 1974 the DMG published a map showing expected maximum acceleration on bedrock throughout the state. Due to a lack of any other information of its type, this small-scale map was widely used as an indicator of the shaking hazard across California. Maximum bedrock acceleration, however, is only one of many variables to be considered in determining the shaking experienced by a structure during an earthquake. The duration of the shaking, for example, is at least as important. Despite its many imperfections, the acceleration map has been used extensively by structural engineers.

While a true "Earthquake Shaking Hazard Map of California" is a long way from realization, DMG is working toward that goal. One related project is a revision of DMG's original Bedrock Acceleration Map. The new map will have the benefit of the earth science research of the last 14 years. About 200 active faults in and adjacent to California were identified and the largest likely earthquake was estimated for each on the basis of the latest scientific opinion. The final product will be a map in which contours or zones represent varying levels of acceleration. Information from the DMG's Strong Motion Instrumentation Program (SMIP) was useful in this project, providing a check of the results shown on this map. Moreover, DMG eventually hopes to produce a map of the probability of earthquake occurrences over specified time periods.

The revised Bedrock Acceleration Map is being generated for the California Department of Transportation (Caltrans), where it will be used for ranking the work of their retrofit program to increase the seismic resistance of some 24,000 highway bridges throughout the state. Also, as in the past, it will be used to scale input ground-motion spectra for designing new highway structures. The list of maximum credible earthquakes determined for the map will, as a by-product, be used in the safety evaluations of hospital sites by private consultants. Draft changes have been made to Title 24 of the State Building Code that will

Photo 11. DMG seismologic instrument aid finishes a concrete slab to install a strong motion instrument on the Vermillion Dam, Thomas Edison Lake in Mammoth County. *Photo by Rich McJunkin.*

Photo 12. SMIP technician installs strong motion accelerometer on a freeway overpass in Southern California. *Photo by SMIP staff.*

require adoption of the published maximum credible earthquakes unless alternative values are supported by new data.

ENGINEERING HAZARDS

Earthquake hazard assessment is only part of the solution to the earthquake shaking problem. Also important is the response of the structures that are damaged and cause deaths. We are fortunate that most wood frame single-family dwellings in California pose little hazard to occupants during earthquake shaking. Other structures have been designed and built to resist the horizontal motions predominant in earthquake shaking.

Improving Building Codes

The ultimate goal of the DMG's Strong Motion Instrumentation Program (SMIP) is to improve building codes. SMIP collects the data that indicate to engineers what changes to the codes are necessary. The code preparation itself is the responsibility of professional engineers rather than of specific government agencies.

To date, SMIP has installed about 400 strong motion stations directly on the ground (Photo 11) and 120 in buildings or on other structures such as bridges (Photo 12). The records collected from these stations after earthquakes show how a structure performs during the earthquake and indicate directions that code improvements may take to improve seismic safety. For example, strong motion records collected from "tilt-up" type warehouse constructions have provided the quantitative basis for improving the codes regulating the fabrication or assembly of wall and roof panels.

Significant records of the motions of a long-span suspension bridge were obtained by SMIP at the Vincent Thomas bridge near Long Beach during the October 1, 1987 Whittier Narrows earthquake (Photo 13). These records, the first ever obtained from such a structure, clearly show the rocking of the bridge deck during the earthquake, and will be compared with earlier studies of the motions of the bridge during traffic and storms.

Records from the nine-story administration building at the California State University at Los Angeles (CSULA) were also obtained during the Whittier earthquake. These records are important because the building has a "soft-first-story" design similar to the Imperial County Services Building in El Centro which was damaged in the 1979 Imperial Valley earthquake. The CSULA building suffered some structural damage in the lower stories, and the SMIP records are being analyzed by an engineering firm studying ways to strengthen the building.

SMIP also has recorded the earthquake shaking of an innovative base-isolated building in Rancho Cucamonga — San Bernardino County's Law and Justice Center. These are the only records of the motion of this type of construction which, by applying shock absorber concepts, may be useful in increasing California's future earthquake safety. So far, the records obtained from this structure have been of small earthquakes but are still important for study by earthquake engineers.

Recent Developments in SMIP

A year after the 1971 San Fernando earthquake, the California Legislature passed, and the Governor signed into law, legislation that created SMIP. SMIP was funded by a fee of $0.07 per $1,000 of new construction. The law directed SMIP to install and maintain strong motion instruments in typical structures and geologic environments of California. Later the law was modified to direct SMIP to also interpret and disseminate strong motion data. Early in the program, SMIP and the Strong Motion Instrumentation Advisory Committee (SMIAC) developed long-range goals that established the type and number of stations to be installed (Table 1).

Photo 13. The Vincent Thomas Bridge in Los Angeles County has been instrumented by SMIP. *Photo by SMIP staff.*

TABLE 1. Type and number of strong motion stations to be installed by SMIP as of the close of the third quarter of Fiscal Year 1987-88 compared to planned network and high-priority subset.

INSTALLATION TYPE	TOTAL PLANNED NETWORK	INSTALLED	TO BE INSTALLED	
			PLANNED	HIGH PRIORITY
Ground Response	520	329	191	117
Buildings	400	90	310	170
Lifelines	95	30	65	38
Total	1,015	449	566	325

Structural types were selected from those building classes thought to be the most important to California. Locations were selected to provide the most significant information return for the instrumentation dollar expended. Many of these high-priority sites were selected because of the view that a great earthquake is likely to occur along the San Andreas fault in Southern California by the year 2005. It was realized in 1986 that, at the current rate of installation (Table 1), the expected great earthquake probably would occur without the highest priority instruments in place to record it.

The original legislation needed to be changed if the highest priority sites were to be instrumented before the expected great earthquake. Legislation passed in 1987: (1) changed the fee structure, (2) allowed a deduction by the county collecting the fee for seismic education, and (3) called for an acceleration in the installation of strong motion instruments throughout California.

A second law allowed SMIP to make a one-time use of surplus funds to begin hiring personnel and purchasing equipment needed for the program expansion. Also included were funds for engineering investigations that would be conducted at California universities focused on the application of the data to building code improvements. These bills ensure that by the year 2005, SMIP will have all high-priority sites and structures instrumented to record the next great California earthquake.

Helping Identify Hazardous Structures

Citizens of the State deserve to feel assured that the buildings they occupy can safely withstand an earthquake. Although no one wants to live in an unsafe building, retrofitting a building to make it safe is expensive. It has been estimated that a major earthquake occurring in one of California's urban areas could result in over 50,000 deaths and could be the greatest natural disaster the U.S. has faced. Most of these deaths can be prevented if appropriate engineering design and retrofitting actions are taken.

Recent legislation, following recommendations of the Seismic Safety Commission, proposes that unreinforced masonry structures in the State be identified. The passage of a bond issue in June 1988 raises the money to begin retrofitting many of these buildings. Funds are limited, however; there will be only enough to retrofit the worst buildings in the most hazardous places.

What are the most hazardous places? Each earthquake presents a few surprises. Sometimes, the epicentral area has little damage, while an adjacent area is devastated. Structural engineers can identify most of the "worst buildings." The discovery of the "worst places" is the responsibility of earth science, but here there is much study that needs to be done.

As shown so clearly by the 1985 Mexico City earthquake, the "best place" for one type of structure may be the "worst place" for another type. Structural engineers, seismologists, geologists, and soil engineers must work together to develop techniques that can be used to determine more precisely the interactions between structures and the materials they are founded upon. The efficiency of any plan to retrofit structures on a statewide basis could be vastly improved with only modest efforts in this direction.

The DMG is participating along with the USGS, local government, academic, and private institutions in various programs to determine the degree of seismic hazard throughout the State. Each of these programs will contribute to the identification of the "worst places."

PREPARATION AND RESPONSE

Earthquake Planning Scenarios

Following the Mount St. Helens eruption in 1980, the Governor of California set up a task force to evaluate and improve the State's earthquake response planning. The DMG took the lead in this effort by supplying maps that showed where the damage would occur for repeats of the great earthquakes of 1857 and 1906 on the San Andreas fault. The maps were included in two earthquake planning scenarios (Special Publications 60 and 61) published in 1982 that focused earthquake preparedness activities in the State. Once the evaluation of the highway system was made by Caltrans, the vulnerability of other regional lifelines (e.g., airports, railways and communication facilities) became obvious. These planning scenarios were speculative and not meant for decisions regarding specific sites, but they accomplished their purpose of drawing attention to the kinds of problems that would arise. The scenarios were used by the Office of Emergency Services (OES) in developing the California Earthquake Response Plan.

Because the San Andreas fault does not traverse all of California's heavily developed areas, other significant active faults within the state's metropolitan areas were also considered. For the San Francisco Bay Area, a scenario was prepared for a magnitude 7.5 earthquake on the Hayward fault (Special Publication 78) and released in December 1987. Such an event would be accompanied by an average of 5 feet of ground displacemet along the fault. The extensive urban development along the fault, combined with the many lifelines crossing it, means that the impact of this earthquake would exceed that of a magnitude 8 event on the San Andreas.

For the Los Angeles area, a scenario was prepared for a magnitude 7 earthquake on the Newport-Inglewood fault which extends through a densely populated area from Beverly Hills to Newport Beach (Photo 14). Again, impact of this earthquake on the region exceeds that of a magnitude 8 earthquake on the San Andreas, which lies primarily northeast of the metropolitan area.

For the magnitude 6 earthquake predicted for the Parkfield area in southeastern Monterey County, a scenario of effects based on the historical record was provided. This was used by OES and local jurisdictions to plan their response to such an event.

Evaluation of an Earthquake Warning System

Earthquake waves travel slowly (2 miles per second) compared to light (186,000 miles per second). Just as one sees lightning before hearing the associated thunder, a network of seismometers, transmitters and receivers might allow one to be aware of the occurrence of a distant earthquake before feeling the associated shaking. An "Earthquake Warning System" could provide warnings of several seconds to half a minute before the onset of strong shaking.

Figure 6 shows how an Earthquake Warning System might work. Figure 7 shows the extent of damage and the possible warning times for the case of a postulated magnitude (M) 7.3 earthquake on the San Andreas fault. The epicenter of the earthquake is near Lebec. The straight, heavy, solid line indicates the extent of surface fault rupture. The heavy oval represents the extent of expected significant damage (in technical terms, the heavy oval represents the extent of Modified Mercalli Intensity VIII or greater on alluvium). The heavy dashed line shows the distance from the San Andreas fault beyond which significant damage (Modified Mercalli Intensity VIII) was not observed after the M 8.0 earthquake of 1852 that occurred on this section of the fault. Thus, significant damage from the postulated earthquake could extend into the

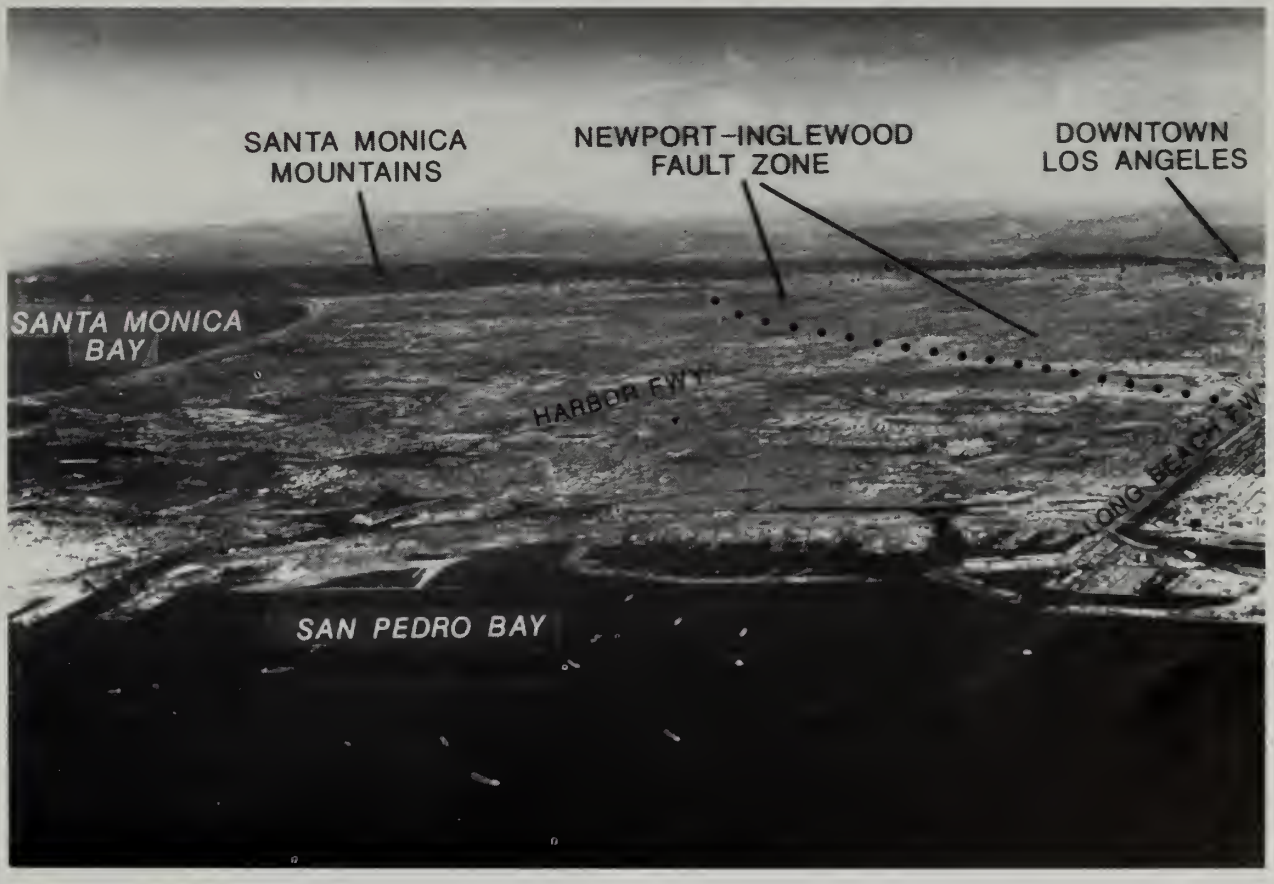


Photo 14. Northerly view of metropolitan Los Angeles from the Harbors to the Santa Monica Mountains. *Photo courtesy of Port of Los Angeles.*

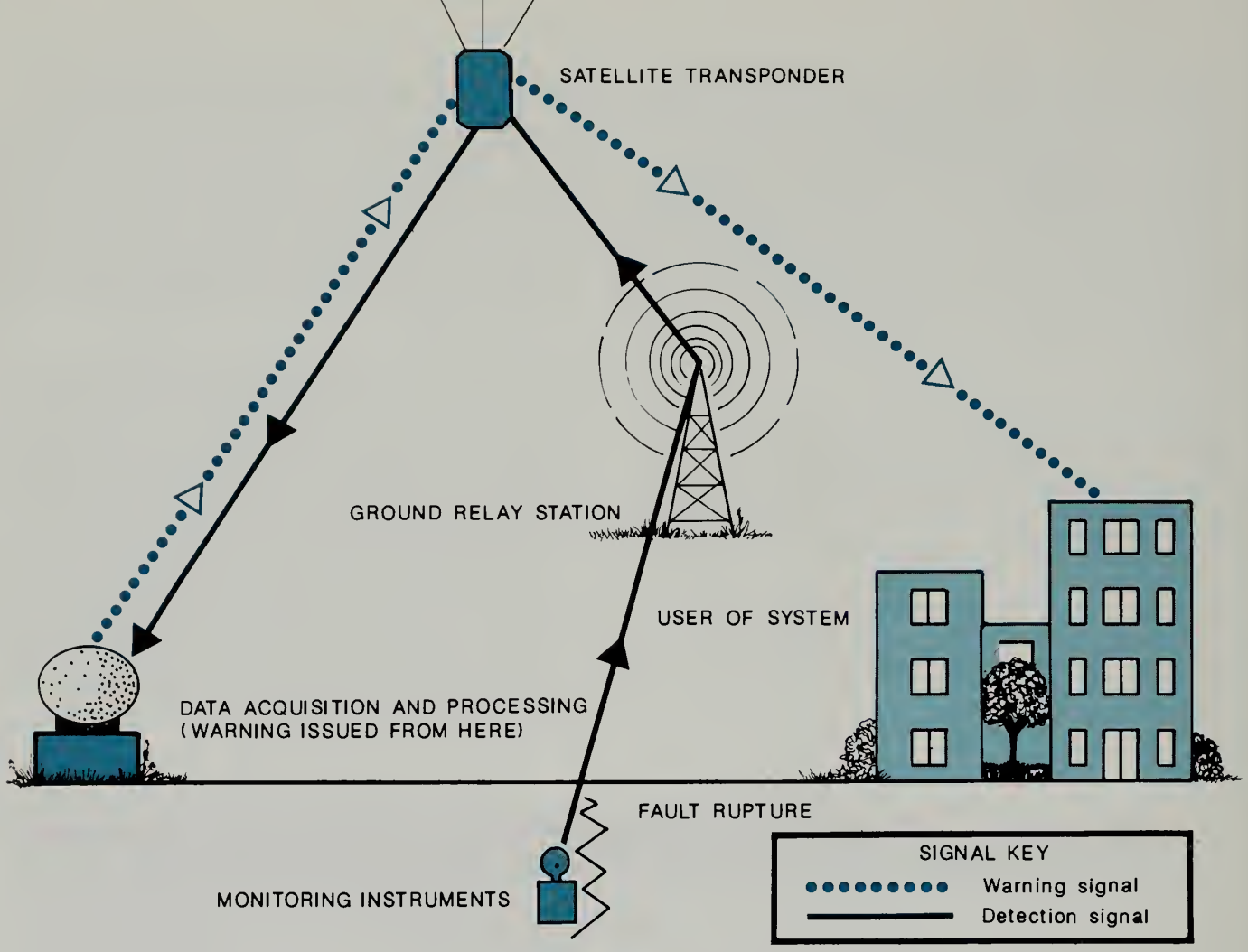


Figure 6. Schematic drawing of an earthquake warning system.

northern San Fernando and San Gabriel valleys, northern Orange County and toward San Bernardino and Riverside.

The large circles on Figure 7, centered on Lebec, indicate the amount of warning time between the earthquake origin and the arrival of strong ground shaking that would be possible under certain conditions and with an assumed system performance. Thus, Bakersfield could receive about 16 seconds of warning while San Bernardino and Riverside would get about 53 seconds of warning.

Evaluating the benefit of such a system is complex. For example, the measure of damage used in Figure 7 (the Modified Mercalli Intensity scale) reflects damage to "short-period" structures, that is one to two stories. Structures that are sensitive to longer periods, such as high-rise buildings, large liquid storage containers and some types of offshore oil platforms, may be affected by large earthquakes at distances greater than those indicated in Figure 7.

Whether such a warning would significantly aid emergency planners or the public is not clear. The DMG is currently conducting a feasibility and benefit/cost study of such a warning system for southern California. Conceptually, the system would consist of a network of closely-spaced seismic instruments monitoring local faults. When initiation of a damaging earthquake is detected by the instrument closest to the epicenter, a central processing system would estimate the size of the earthquake and, if warranted, issue a warning to distant user systems capable of receiving its signal. Thus, up to several tens of seconds, depending on earthquake size and distance of the user to the epicenter, could be available for initiation of some mitigating action before damaging shaking arrives.

The study will evaluate the benefits of such a system to various elements of society, including public officials, schools, hospitals, police, fire stations, utilities, private industry, critical defense contractors, and gas, oil and electrical industries. Representatives of these possible users were queried about potential uses of a warning, necessary warning times, potential savings, and costs of false alarms. The DMG staff is compiling and interpreting the responses in terms of the design requirements of such a system. Funding, management, and legal issues also are being examined. A report will be sent to the Governor in early 1989.

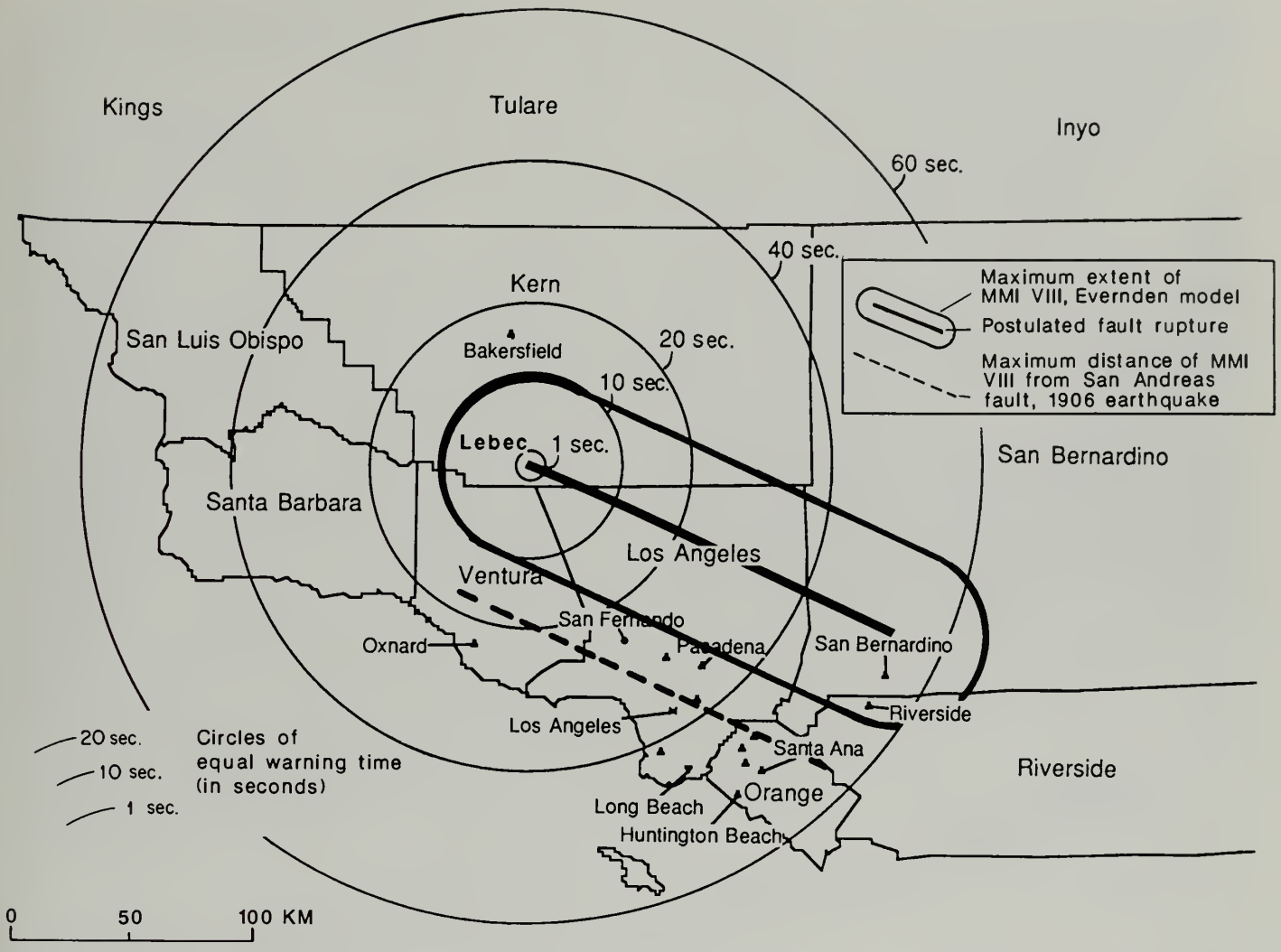


Figure 7. Postulated magnitude 7.3 earthquake on the Mojave segment of the San Andreas fault epicenter near Lebec.

VOLCANIC HAZARDS

ISSUE: *Parts of the State are subject to volcanic eruptions that could take lives and destroy property.*

In May 1980, two separate geologic events fundamentally changed the public perception of volcanic hazards in the continental U.S. On May 18, Mount St. Helens erupted catastrophically, killing 67 people and spreading a blanket of volcanic ash over much of eastern Washington. Besides raising the public's awareness of volcanoes, the events of May 18 and the next few days provided a wealth of information on emergency response efforts. Such an eruption had not been experienced in this country during the last half century.

One week later, On May 25, 1980, a magnitude 6 earthquake occurred near the community of Mammoth Lakes in California. Over the next two days, three additional events with magnitudes greater than 6 occurred, along with hundreds of small aftershocks. The occurrence of these four magnitude 6 earthquakes, over such a short period and in such a small area, served as a reminder that California's Long Valley also is an active volcanic system (Photo 15). Repeated earthquake swarms, uplift of the ground, and increased hot spring activity over the next two and one-half years prolonged this concern.

In the last few years, both the State and Federal governments have taken steps to improve volcanic hazards assessment capabilities in order to increase public safety in the Mammoth Lakes area.

Photo 15. Mono-Inyo chain of volcanic domes and craters in Mono County. *Photo by DMG staff.*

The DMG set up the Volcanic Hazards Monitoring Program in which a computer system is used to record and analyze earthquakes automatically, in the search for anomalous events. The USGS monitors seismicity, tilt, leveling, strain, and geochemistry. The DMG and USGS share data and experience in order to evaluate the potential of increased volanic activity in the Mammoth Lakes area.

Because much can be learned from the experience with volcanic hazard warning systems in other states, the DMG maintains extensive contacts with those programs and keeps abreast of the latest techniques. For example, the University of Nevada at Reno also monitors seismic activity in the Long Valley area, sharing data and experience with the DMG. As part of DMG's program, disaster planning documents have been prepared in cooperation with OES, Mono County, and Inyo County.

LANDSLIDES HAZARDS

ISSUE: *Population expansion is forcing construction onto hillsides where the ground commonly is unstable, presenting a threat to lives and property.*

Slope failures are caused by conditions such as steep slopes, weak rocks, abnormally wet winters, and sporadic intense rainstorms. Urban encroachment upon slopes subject to these natural conditions can result in loss of lives and severe property damage. These conditions are common in California (Photo 16).

Losses due to landslides in California approach $200 million per year. As mentioned in *Urban Geology*, proper planning and grading code enforcement could reduce future losses by 90 percent. The effectiveness of mitigation is dependent on adequate, detailed landslide hazard information. The State, through the products of the DMG's investigations into landslide-prone terrain, helps local government avoid and reduce landslide-related losses.

Landslides tend to occur where landslides have occurred before. Landslide mapping, therefore, is the primary method for reducing the problem prior to development. Landslide mapping by the DMG began in 1960 in the Palos Verdes Hills of Los Angeles Couinty as the initial project in a cooperative program with local government.

Increased emphasis on investigations of geologic hazards, such as landslides, followed passage of legislation in 1965 that enabled the DMG to establish cost-sharing and cooperative agreements with local governmental agencies, other State agencies, and Federal agencies. Work was done in the counties of Los Angeles, Orange, San Bernardino, Sonoma, Ventura, Marin, and Santa Clara as well as in many cities.

Geohazard information provided to local governments was used in the preparation of safety elements of general plans and in the review of applications for building permits. These State and local government cooperative agreements ended with the passage of Proposition 13 in 1978.

In March 1980, for the first time, the DMG was authorized, required, and funded by legislative act to carry out a specific slope stability investigation. This study, published as Special Report 152, covered the Baldwin Hills section of Los Angeles, an area especially hard-hit by storm-related slope failures in 1969, 1978, and 1980.

The landslide disasters experienced by many parts of the State in 1982 stimulated passage of the Landslide Hazard Identification Act in 1983 — the first such statute passed by any state. The Act formally established a Landslide Hazard Investigation Program in the Department of Conservation and charged the DMG to develop maps of landslide hazards in urban and rapidly urbanizing areas of the State. During its first four years, the Landslide Hazard Identification Program prepared maps covering approximately 1,200 square miles in both northern and southern California. The maps were published as sets that include inventories of existing landslides, geologic maps, and interpretative maps of related landslide and debris-flow susceptibility. Land use planners in local agencies report using the maps in concert with non-geologic types of data. In addition, the maps are used by public works agencies as a guide to evaluate requirements for geotechnical studies during the review of applications for building permits.

In 1988, legislation was passed that permits the Program to continue mapping landslide hazards through January 1, 1995.

Responsibility for taking action to reduce losses from landslide activity ultimately rests with local government because it, alone, is empowered to regulate land use

Photo 16. Landslide triggered by the 1971 San Fernando earthquake (magnitude 6.4). This landslide occurred just north of the Los Angeles Basin next to where construction on Interstate Freeway 5 was underway. *Photo courtesy of the California Department of Transportation.*

within its jurisdiction. Among the various approaches used to reduce landslide hazards are land use planning and zoning strategies that focus on diverting, diminishing, or discouraging development on unstable hillsides. Landslide maps precede zoning ordinances.

The mitigation of the landslide problem is driven by the availability of landslide maps. The best example is San Mateo County. Here, the USGS has produced detailed and appropriate landslide hazard mapping as an example of what could be done by State and local government. The county is now a showcase of responsible local use of landslide maps for establishing a resource management zoning district. Within the district, the permitted dwelling density varies depending on the severity of the slope stability problem. Large lot sizes, for example, sometimes improve the chances for construction on stable ground and decrease the overall impact on the community if and when landslides do occur.

URBAN GEOLOGIC MAPPING

ISSUE: *A new series of geologic maps is needed for land use planning in California's urban areas.*

Geologic maps of different scales serve different purposes. In the past, the DMG, charged with the task of preparing a geologic map of the state, compiled the geology at scales of 1:250,000 (about 4 miles to the inch) and 1:750,000 (about 12 miles to the inch). While these maps are excellent for mineral exploration and for studies of geohazards on a regional basis, their scales are inadequate for most land use planning purposes.

California's continuing urban growth has stimulated demand for earth science information with more detail than any of the above-mentioned maps can offer. The USGS's new 1:100,000 scale topographic maps for urban areas make a useful map for regional planning: a one-meter square on such a map represents a 100 kilometer (60 mile) square section of terrain. This scale portrays enough detail for studying fault segmentation, geologic offsets, and landslides.

A vigorous effort by many groups in identifying geologic hazards in urban areas during the last two decades has yielded considerable new geologic data. By using these data, and by filling in where little exists, DMG has begun to map urban and urbanizing areas at the 1:100,000 scale. Work is currently in progress adjacent to the San Francisco and Los Angeles metropolitan areas.

CONCLUSIONS

Californians have benefited significantly from the mineral resource and geologic hazard activities of the DMG during Fiscal Year 1987-88. Moreover, the stage has been set for continued benefits during coming years.

MINERAL RESOURCES

- *Urban Geology* predicted that $15 billion of loss of mineral resources to development could be prevented. DMG's Urban SMARA program has identified aggregate deposits within urban areas worth 20 times that amount. SMARA has provided local jurisdictions with sufficient information to preserve these sand and gravel resources from urban encroachment.

- The Non-Urban SMARA program has provided evaluations of mineral potential in the Sierra foothills and the Mojave Desert to enable public officials to make wise land use decisions.

- The potential for significant mineral resources in the offshore region can be more accurately evaluated now that DMG-USGS geologic maps of the offshore area are being released.

- Mined land reclamation is proceeding apace for new mining operations and is now being required of operations that existed before SMARA.

GEOLOGIC HAZARDS

- California has made great strides in preparing for future damaging earthquakes, but much remains to be done. The DMG earthquake planning scenarios have stimulated major improvements in disaster planning. Amid speculations that a great earthquake could hit southern California before the turn of the century, steps are being taken to identify and retrofit hazardous structures. Structural engineers are identifying the "worst structures" while earth scientists are delineating the "worst places." The DMG has programs to estimate the activity of faults and shaking hazards.

- The Strong Motion Instrumentation Program continues to supply the basic data that will be used to improve building codes for seismic safety. This Program has been accelerated in preparation for the great earthquake that many scientists expect before the turn of the century. An earthquake warning system is being evaluated that could provide warning of shaking from distant large earthquakes.

- The hazard due to surface fault rupture is being mitigated as the Alquist-Priolo Special Studies Zones Act completes its decade-long program to zone all active faults in the state.

- The possibility of volcanic eruption is being monitored by a special program concentrating on the Mammoth Lakes area.

- The DMG's landslide mapping program was reinstituted in order to precede development on the urban fringe. Zoning ordinances of local governments continue to be the most effective ways to deal with slope stability problems. Without landslide maps, these ordinances cannot be implemented.

URBAN GEOLOGIC MAPPING

- DMG has begun large-scale geologic mapping in California's urban areas by using the new USGS 1:100,000 topographic bases.

APPENDIX

LIST OF PROJECTS CONDUCTED BY THE DIVISION OF MINES AND GEOLOGY DURING FISCAL YEAR 1987-88.

1. Regional Geologic Mapping Program
2. Alquist-Priolo Fault Evaluation Project
3. Earthquake Damage and History
4. Strong Motion Instrumentation Program
5. Cal Tech Seismographic Network Support
6. Environmental Review
7. Library Services
8. Landslide Hazard Identification Program
9. Earthquake Notification and Volcanic Hazards
10. Earthquake Shaking Assessment
11. Timber Harvest Plan Review
12. USGS Newport-Inglewood Earthquake Scenario Project
13. OSA Hospital Site Review
14. USGS San Gabriel Fault Study Project
15. Mineral Resource Appraisal Program
16. Applied Geophysics Program
17. Urban SMARA Program
18. Country SMARA Program
19. Reclamation SMARA Program
20. State Mining and Geology Board
21. Information and Publications

LIST OF 1987-88 PUBLICATIONS OF THE DIVISION OF MINES AND GEOLOGY.

BULLETINS

BULLETIN 206 — Geology and Ore Deposits of the Bodie Mining District, Mono County, California. By Roger Chapman and Cliffton H. Gray, Jr., 1987, 35 p. Plates 1-5. $18.00.

BULLETIN 207 — Geology of the California Continental Margin: Explanation of the California Continental Margin Geologic Map Series. By Michael P. Kennedy, H. Gary Greene, and Samuel H. Clarke, 1988, 110 p. Plate 1. $15.00.

SPECIAL REPORTS

SPECIAL REPORT 151 — Uranium Favorability of the Trona 1° by 2° Quadrangle, Mojave Desert, California. By Marjorie M. Bushnell and Paul K. Morton, 1987, 43 p. Plates 1-2. $6.00.

SPECIAL PUBLICATIONS

SPECIAL PUBLICATION 78 — Earthquake Planning Scenario for a Magnitude 7.5 Earthquake on the Hayward Fault in the San Francisco Bay Area. By Karl V. Steinbrugge, John H. Bennett, Henry J. Lagorio, James F. Davis, Glenn Borchardt, and Tousson Toppozada. Consultants: Henry J. Degenkolb, Gordon L. Laverty, and James E. McCarty, 1987, 242 p. $4.00.

SPECIAL PUBLICATION 93 — Mines and Mineral Producers Active in California During 1986. By DMG Staff, 1987, 99 p. $4.00.

SPECIAL PUBLICATION 94 — Minerals for Industry Northern California, Volume II. Summary of Geologic Survey 1955-1961. Re-released by permission of Santa Fe Southern Pacific Corporation, 1987, 207 p. Plate I, II. $10.00.

SPECIAL PUBLICATION 95 — Minerals for Industry Southern California, Volume III. Summary of Geological Survey 1955-1961. Re-released by permission of Santa Fe Pacific Corporation, 1987, 242 p. Plate I-IV. $10.00.

SPECIAL PUBLICATION 96 — Geology of San Diego County: A bibliography with subject index. By Elizabeth Harris, San Diego State University, 1987, 68 p. $3.00.

REGIONAL GEOLOGIC MAP SERIES

Geologic Map of the Weed 1° by 2° Quadrangle, California. By D.L. Wagner and G.J. Saucedo. Scale 1:250,000. 4 Sheets: Sheet 1 (Geology), Sheet 2 (Geologic legend), Sheet 3 (Index to geologic mapping), Sheet 4 (Radiometric age of rocks). 1988. $15.00.

MAP SHEET SERIES

MAP SHEET 43 — Total Field Magnetic Anomaly Map Cascade Mountain Range, Northern California, By R. Couch, M. Gemperle, G. Connard, W. McLain, and J. Huppunen. Scale 1:250,000. Supplements A, B. 1988. $3.00.

CALIFORNIA CONTINENTAL MARGIN GEOLOGIC MAP SERIES

Geology of the Inner-Southern California Margin, Area 1 of 7. H. Gary Green and Michael P. Kennedy, editors. Scale 1:250,000. Map 1A (Geology), Map 1B (Selected fault plane solutions and earthquake epicenters), Map 1C (Gravity and magnetic anomaly), Map 1D (Well, trackline, and data source). 1988. $13.00.

Geology of the Outer-Southern Continental Margin, Area 3 of 7. H. Gary Greene and Michael P. Kennedy, editors. Scale 1:250,000. Map 3A (Geology), Map 3B (Selected fault plane solutions and earthquake epicenters), Map 3C (Gravity and magnetic anomaly), Map 3D (Well, trackline, and data source). 1988. $13.00.

DMG OPEN-FILE REPORTS

DMG OFR 86-17 — Landslide Hazards in the Benicia-Vallejo Area, Solano County, California: Landslide Hazard Identification Map No. 8 — by Edward J. Bortugno.

DMG OFR 87-3 — Aeromagnetic Map of the Chico 1° by 2° Quadrangle, California — by Leslie G. Youngs.

DMG OFR 87-4 — Aeromagnetic Map of the San Francisco/San Jose 1° by 2° Quadrangle, California — by Gordon W. Chase.

DMG OFR 87-5 — Aeromagnetic Map of the Trona/Kingman 1° by 3.5° Quadrangle, California — by Leslie G. Youngs.

DMG OFR 87-7 — Surface and Groundwater Management in Surface Mined Land Reclamation — by Barbara Evoy and Mel Holland.

DMG OFR 87-8 — Landslide Hazards in the North Half of the Oat Mountain Quadrangle, Los Angeles County, California: Landslide Hazard Identification Map No. 10 — by Jerome A. Treiman.

DMG OFR 87-9 — Landslide Hazards in the South Half of Fairfield North Quadrangle, Solano County, California: Landslide Hazard Identification Map No. 11 — by Hasmukhrai H. Majmundar.

DMG OFR 88-1 — Summary Report: Fault Evaluation Program, 1986-1987, Mojave Desert Region and Other Areas — by Earl W. Hart, William A. Bryant, James E. Kahle, Michael W. Manson, Edward J. Bortugno.

DMG OFR 88-3 — Mineral Land Classification of the Kerens, Flynn, and Colton Well 15-Minute Quadrangles, San Bernardino County, California — by Ralph C. Loyd.

DMG Open-File Reports Worked on during FY 1987-88; To Be Released in FY-1987-88 or Early in FY-1988-89.

DMG OFR 87-6 — Geology of the Iaqua Buttes 15-Minute Quadrangle, Humboldt County, California — by Harvey M. Kelsey and Alan O. Allwardt.

DMG OFR 87-10 — Reconnaissance Geologic Map of Parts of the Wingate Wash, Quail Mountains, and Manly Peak 15-Minute Quadrangles, Inyo and San Bernardino Counties, California — by David L. Wagner and Eugene Y. Hsu.

DMG OFR 88-5 — Preliminary Geologic Map of the Northwest Quarter of the Santa Rosa 7.5-Minute Quadrangle, Sonora County, California — by Charles W. Jennings.

DMG OFR 88-7 — Aeromagnetic Map of the Monterey 1° by 2.2° Quadrangle, California — by Leslie G. Youngs.

DMG OFR 88-8 — Aeromagnetic Map of the Santa Ana 1° by 2° Quadrangle, California — by Leslie G. Youngs.

DMG OFR 88-9 — Aeromagnetic Map of the San Diego and El Centro 0.5° by 2° Quadrangles, California — by Leslie G. Youngs.

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